CURRENT LITERATURE

NOTES FOR STUDENTS

Light and growth.—BAKHUIJZEN[1] gives a theoretical discussion of the possibility of photo-growth response as the basis of phototropic reaction. He accepts BLAAUW'S[2] view that the effect of light on the longitudinal growth is the basis of phototropic response, which is the resultant of the effect of unilateral light on the growth of the two flanks of the plant organ. This is DE CONDALLIS' old theory of phototropic response. He calculates VOGT'S data on the *Avena* coleoptile, which he believes confirms this view. From this work he believes that the retarding effect of a given dosage of light accounts for the phototropic response, and that the later accelerating effect is not involved. He finds that the effect of omnilateral fore-illumination on later phototropic response to unilateral illumination can be explained by the joint effect of the two kinds of illumination upon the growth of the two flanks, and that there is no necessity of assuming that omnilateral illumination changes the sensitiveness of the organ. This agrees more nearly with ARISZ' interpretation of his results, and is quite opposite to the view of BREMEKAMP. CLARK'S results, in which he found that omnilateral fore-illumination increased the sensitiveness of the organ in negative phototropic response, can be similarly explained. The time during which the light is applied, as well as the total energy, is important, and this will explain the results obtained by unilateral illuminations followed by omnilateral illuminations on the photo-growth basis.

LAURENS and HOOKER,[3] working on *Volvox* with various ray lengths of equal energy value, find that wave length λ 494 $\mu\mu$ has the highest stimulative value, and that the efficiency decreases with both shorter and longer wave lengths. The measurements were made both on the basis of relative duration of the presentation time and the relative rate of locomotion (and precision of orientation). Other authors have found the optimum for photo-perception and photo-growth response for various forms in this general region of the spectrum.

GUTTENBURG[4] has shown by several methods that in the coleoptile of *Avena sativa* the total plane of unilateral illumination is quite as important in

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[1] BAKHUIJZEN, H. L., VAN DE SANDE, Photo-growth reaction and disposition to light in *Avena sativa*. Konin. Akad. Weten. Amster. **22**:1–16. 1919.

[2] BOT. GAZ. **59**:67–68. 1915.

[3] LAURENS, H., and HOOKER, H. D., JR., Studies on the relative physiological value of spectral light. II. The sensibility of *Volvox* to wave-lengths of equal energy content. Jour. Exp. Zool. **30**:345–368. 1920.

[4] GUTTENBURG, H. V., Untersuchungen über den Phototropismus der Pflanzen. I. Über die Abhängigkeit der phototropen Erscheinungen von der Grösse der Beleuchteten Flache. Ber. Bot. Gesells. **37**:299–304. 1919.

determining photo-presentation as the light intensity or the duration of light exposure.

GUTTENBURG[5] has also worked on the question of whether it is the direction of the ray or the relative intensity of the light on the two flanks of the plant organ that determines the phototropic orientation. His evidence points to the former as the determining factor. It is doubtful, however, whether his methods are to be compared in reliability with those of MAST,[6] which seem to prove the intensity theory.

SCHANZ[7] has just published a striking article on the effect of light of different ray lengths on the development of plants. This is one of the very rare articles that makes a really large contribution to the subject. This is assuming, of course, that his results and conclusions will be confirmed by later work. The plants were grown in beds covered with glass of various kinds that cut out different regions of the spectrum. The nine beds received the following light: (I) without cover, ray lengths λ 300 $\mu\mu$ and longer; (II) covered with ordinary window glass, ray lengths λ 320 $\mu\mu$ and longer; (III) euphos (*a*) glass only, ray lengths λ 380 $\mu\mu$ and longer; (IV) euphos (*b*) glass only, ray lengths λ 420 $\mu\mu$ and longer; (V) red glass only, ray lengths λ 560 $\mu\mu$ and longer. By combining yellow, green, and blue violet glass with euphos glass he got yellow, green, and blue violet lights respectively that were free from most of the ultra violet rays. He numbered the yellow VI, the green VII, and the blue violet VIII.

Cucumbers grown in these beds showed a rather rapid increase in rate of growth and vigor as one passed from bed I to bed V; that is, as more and more of the ultra violet and other short rays were removed. From bed V to VIII the rate of growth and vigor fell off. The curve representing the growth rate in the various beds was a mathematical curve with the peak at V. *Petunia*, *Fuchsia*, *Chrysanthemum*, *Lobelia*, *Begonia*, and *Oxalis esculenta* showed similar curves. In fact, practically all of the plants studied showed similar behavior in the rising part of the curve (beds I to V), but several showed irregularities in the falling part of the curve (beds VI to VIII). The potato was weakest in yellow, stronger in green, and still stronger in blue violet. In green lettuce the leaves became continuously longer and more slender as one passed from beds I to V. They were very slender in red, and there was a misproportion between midrib and flat portion of the leaf. In yellow the disturbance was still greater and the plants showed poor chlorophyll development. In green these plants showed similar but less marked dis-

[5] GUTTENBURG, H. V., Untersuchungen über den Phototropismus der Pflanzen. II. Neue Versuche zur Frage nach der Art der Lichtperception. Ber. Bot. Gesells. 37:304–310. 1919.

[6] BOT. GAZ. 51:304–305. 1911.

[7] SCHANZ, FRITZ, Wirkungen des Lichts verschiedener Wellenlänge auf die Pflanzen. Ber. Bot. Gesells. 37:430–442. 1919.

turbances. In blue violet they were more vigorous and deep green. In short, the green lettuce showed a deficiency in chlorophyll development in yellow and green lights. Some other irregularities appeared in certain other plants.

The blooming was earlier (green lettuce, *Fuchsia*, beans, tomatoes) as one passed from bed I to IV; that is, the euphos glass, which cut out much of the ultra violet rays, favored early blooming to a marked degree. The number of fruits increased from bed I to IV. In red, yellow, green, and blue violet the blooming was deferred and the number of fruits reduced.

The ultra violet rays have a very important relation to anthocyanin development in the epidermal layer. In red-leaved lettuce the red color fell as one passed from bed I to bed III where no red developed. No anthocyanin developed in beds IV to VIII. *Celosia Thomsoni*, red-leaved begonia, and red-leaved beet acted similarly, except that anthocyanin developed in the midribs and petioles of the last in all the beds. When any of these plants were grown in beds where anthocyanin did not develop, and were then transferred to bed I, anthocyanin began to appear in 2 days and was fully developed in 8 days. When plants grown in bed I and bearing anthocyanin were transferred to beds III to VIII, the new leaves unfolding in the latter beds were without anthocyanin.

In all plants except one SCHANZ found no evidence that the red pigment functioned in protecting the plant against the injurious action of the ultra violet of the solar spectrum; for when plants were transferred from bed IV, where no red pigment developed, to bed I, no injury appeared, but the leaves soon developed the pigment. Red beech was the exception. When this plant was transferred from bed IV to bed I, the old leaves without pigment died within a few days, and the new leaves unfolding developed the red pigment.

The rate and percentage of germination of seeds (lettuce and stinging nettle) increased from bed I to bed IV. Repeated cultures on these forms showed that ultra violet interferes with germination.

When etiolated seedlings (bush beans, soy beans, potatoes) were transferred to the beds, the order of greening, beginning with the fastest, was red, euphos *b*, euphos *a*, ordinary glass, open bed, yellow, green, blue violet. The development of chlorophyll is favored by a greater and greater removal of the ultra violet. Also chlorophyll decomposition is deferred in old plants by screening out the ultra violet rays.

SCHANZ mentions the fact that in Holland many growers prefer crude glass to regular window glass for forcing houses. He finds that crude glass cuts out more of all rays than window glass, but that it is especially effective in screening out ultra violet, and concludes that any possible detrimental effect from reducing light intensity for synthesis is more than counteracted by the benefits derived from screening out injurious ultra violet rays.

From these results it seems evident that SCHANZ was fully justified in his earlier statement that ultra violet light of the solar spectrum has a remarkable effect on the development of plants.

In his very extensive work KLEBS has always maintained that the action of red light was due to the fact that it has high photosynthetic action. SCHANZ's work suggests that the effect may be due in part to the fact that it eliminates detrimental ultra violet rays.

This very important work of SCHANZ merits checking up and extending. The work with ultra violet light has been largely with artificial spectra much richer in ultra violet than the solar spectrum, and too little exact study has been made of the formative effects of the ultra violet of the latter spectrum.

A very noteworthy piece of work by GARNER and ALLARD,[8] reviewed in detail elsewhere in this journal, should be mentioned in this connection. It is possible that the remarkable effects they obtain from length of day is due to the fact that it modifies the nitrogen *carbohydrate* ratio of which FISCHER, KRAUS and KRAYBILL,[9] and others have made so much as a determiner of the course of development, whether vegetation shall dominate or there shall be a balance of vegetation and reproduction.

In the small dosages of light used in phototropic and photo-growth response, the most effective region of the spectrum on the basis of equal energy value lies at λ 505 $\mu\mu$ for the sporangiophore of *Phycomyces;* at λ 467 $\mu\mu$ for the coleoptile of *Avena;* and at λ 494 $\mu\mu$ for *Volvox,* as previously given. Perhaps with the high dosage of natural illumination the effective region shifts still more to the right as is indicated by SCHANZ's work.

A comprehensive study of the formative effect of light on plants is much needed to see to what degree its formative action is due to synthetic activity, to the so-called photo-growth responses, to various effects of ultra violet rays, and to other effects not included in these.—WM. CROCKER.

Effect of light exposure on plant growth.—GARNER and ALLARD[10] have grown plants under different conditions of light exposure, and have made a special study of the tendency to become reproductive or to remain vegetative under varying daily lengths and intensities of exposure. Several varieties of tobacco and soy bean were mainly used in the experimental work, although numerous other species of annuals and biennials were used to check the results attained.

Plants were grown in pots, buckets, or boxes, and at the desired time each day were moved into dark chambers which were placed in the field. For the last season's work, large dark houses were constructed, in such a way that plants could be moved in or out at any time. Time of exposure to light

[8] GARNER, W. W., and ALLARD, H.A., Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agric. Res. **18**:553–606. 1920.

[9] BOT. GAZ. **67**:445–446. 1919.

[10] GARNER, W.W., and ALLARD, H. A., Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agric. Res. **18**:553–606. 1920.